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Policies for forest landscape management – A conceptual approach with an empirical application for Swedish conditions

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ABSTRACT

Habitat loss and habitat fragmentation are major factors leading to forest biodiversity decline. This paper discusses landscape planning as strategy to improve connectivity in a landscape with a heterogeneous distribution of ecologically valuable areas across land owners. A tax-fund system is proposed, that following the principle of common but differentiated responsibility, tries to spread the burden of conservation equally across land owners while optimizing the environmental outcome. Design options of such a tax-fund system are discussed along the lines of a simple theoretical model. Financial effects of a tax-fund system are computed for a small model landscape set in Sweden. Two design questions stand out as particularly important. The first is whether the policy is intended to be self-sustained among the land owners or if the budget can be supplemented by general tax money. The second is whether the land owners or the relevant authority select the stands for conservation set-aside.

1. Introduction

Globally, a major driver of biodiversity loss in general, and in forests in specific, is habitat destruction (Haddad et al., 2015). Habitat destruction can be seen as a combination of two different phenomena – habitat loss and habitat fragmentation (Fahrig, 2003). In this paper we suggest that landscape approaches may be a way forward to decrease habitat destruction and to help countries comply with the targets and obligations set out by international agreements. At the international level, the 20 Aichi Biodiversity Targets which form a part of the Convention of Biological Diversity's (CBD) Strategic Plan for Biodiversity 2011–2020 are important milestones (CBD, 2010). Target 11 states the ambition to, by 2020, conserve at least 17% of terrestrial areas through effectively and equitably managed, ecologically representative and well-connected systems of protected areas and other effective area-based conservation measures that are integrated into the wider landscapes. Within the EU, the EU habitat directive (Council Directive 92/43/EEC), also called Natura2000, in addition obliges member states to establish a strict protection regime for some of the listed species, including the protection of breeding sites and resting places.

Spatially, Aichi target nr. 11 refers to the landscape scale. "Landscape", per se, is a widely used term which has several distinct connotations. Conceptually, landscape definitions can be categorized into environment-centered approaches (e.g. in Piorr, 2003 and human-centered approaches (e.g. as in the European Landscape Convention). Taking a perspective between the two definitions above Sayer et al. (2013) argue that a landscape can be seen as an arena or dynamic system which is governed by ecological, physical and societal rules and relationships. The landscape boundary is defined by the actors' objectives. Thus from this perspective, the landscape relevant to an environmental policy maker may be equivalent to his or her jurisdiction while the landscape relevant, for example, to a single forest estate owner within that jurisdiction may be significantly smaller.

Although landscape planning for conservation may seem a fairly straightforward approach to improve connectivity of ecologically valuable areas, policy design becomes difficult when land owners are unequally affected by restrictions. Few studies address policy analysis in this area and little is known about financial effects of different policy approaches for forest owners (Parkhurst et al., 2002; Parkhurst and Shogren, 2007; Bell et al., 2016).

This paper adds to this literature by proposing a tax-fund system, in which forest owners pay a certain tax and the funds generated through the tax are used to compensate forest owners that are required to set-aside land for conservation purposes. We develop a simple theoretical model to help explain the structure of this tax-fund system. To gain first empirical insights on the tax-fund system, we chose Sweden as a case study. A workshop conducted with forest stakeholders in Sweden allows us to derive an understanding of the relative importance of different

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design aspects of such a tax-fund system in practice. Moreover, in order to shed light on financial effects of different policies in heterogeneous landscapes with unequal distributions of ecological value across forest estates, we present simulation results for a small model landscape set in Sweden. A major question is whether the land owners can achieve an optimal allocation of conservation sites at least costs by means of a self-sustained tax-fund system, or whether additional government funding is necessary to achieve the optimal solution.

2. Model and methods

Within a forest landscape, stands of high conservation value are unlikely to be equally distributed across forest owners. Implementing a landscape approach for conservation will thus result in unequal burdens among forest owners, with some required to set aside large amounts of forest while others may need to only set aside little or none at all. A tax-fund system follows the principle of common but differentiated responsibility, in the sense that all forest owners are responsible for conservation and are obliged to contribute. At the same time there is differentiation in the share of set aside between land owners, given the unequal distribution of ecologically valuable sites. Building on the common responsibility of all forest owners, the tax-fund system seeks to level out these differences by imposing a tax on non-conserved land. The funds generated through the tax are used to compensate for the opportunity cost of the conserved land. Internationally, there is a nascent interest in this type of tax-fund system in forestry, see e.g. the California lumber tax of which proceeds are, inter alia, used to reduce the costs of wild land fire suppression (Bill number AB1492).

Below, we first present a model that serves as background for the case study set in Sweden. Section 2.2.1 presents the workshop survey method and Section 2.2.2 introduces the simulation methods for the financial effects analysis.

2.1. Model

A simple model of a social planner's problem Eq. (1) and a representative forest owner's problem Eq. (3) is developed to help structure the discussion of issues around the proposed tax-fund system. The social planner's choice variable is the amount of land for conservation in the landscape. The forest owner's choice variable is the amount of productive land, as opposed to set aside land for conservation, within the limits of his own estate. Set in the framework of a tax-fund system, the social planner seeks to determine the optimal amount of conservation area by balancing environmental benefits against opportunity costs of conservation. The forest owner maximizes private income by choosing the optimal amount of productive land, while taking into account the incentives generated by the tax-fund system.

The superscript “SP” stands for social planner and “f” for forest owner. In the following, capital letters stand for variables at landscape scale and lower case letters stand for the private forest owner scale.

The landscape consists of L ha of forest land. The land constraint is given by $L = X + Q$, where X are the hectares that are conserved in the entire landscape and Q is the non-conserved forest area. Equivalently, the forest owner's estate consists of $l = x + q$, where x is the area of conserved land and q is the area of non-conserved land that belongs to the forest owner.

The environmental benefit of the conserved land in monetary units is given by the function $\alpha(X, z)$, with $\partial\alpha/\partial X > 0$ and $\partial^2\alpha/\partial X^2 < 0$; and depends on area, X, and certain characteristics relevant for biodiversity, z. The opportunity cost is expressed by $\rho(X, v)$, $\partial\rho/\partial X > 0$ and depending on the stand characteristics $\partial^2\rho/\partial X^2 \geq 0$ or $\partial^2\rho/\partial X^2 \leq 0$; which is the present value of the land for timber production. It is a function of area, X, and certain land characteristics, v.

The social planner's tax income function for the non-conserved land at landscape scale, $\tau(Q, v, z, S)$, with $\partial\tau/\partial Q > 0$ is a function of the non-conserved area, Q, and the biodiversity and land characteristics v and z. The fund can also be alimented by society at large, i.e. through a share of the country's general tax income, S. The conservation reward function which compensates the forest owner, $t(x, v, z)$, with $\partial t/\partial x > 0$ depends on the conserved area x and land characteristics v and z.

2.1.1. Social planner's problem

The social planner's problem in Eq. (1) is thus to choose the amount of land to conserve, X, to maximize the environmental benefit of the conserved land subtractive of its cost of conservation subject to the constraint that the tax income is equal to the amount required for compensation and the land constraint. The social planner's first order condition is given in Eq. (2), where λ is the Lagrange multiplier and the land constraint has been substituted into the first constraint. It states that marginal benefit and marginal cost of the amount of conserved land should be equal.

$$\varphi^{SP} = max_X [\alpha(X, z) - \rho(X, v)] \tag{1}$$

s.t. $\rho(X, v) = \tau(Q, v, z, S)$ and $L = X + Q$, with $L, X, Q \geq 0$

$$\frac{\partial\alpha}{\partial X} - \frac{\partial\rho}{\partial X} + \lambda\left(\frac{\partial\tau}{\partial X} - \frac{\partial\rho}{\partial X}\right) = 0 \tag{2}$$

2.1.2. Forest owner's problem

The forest owner chooses the amount of productive land, i.e. non-conserved land, to maximize private income. In Eq. (3) this is composed of the present value of the production area minus the tax on this land plus the compensation for the conserved land subject to his land constraint. In Eq. (4) the land constraint has been substituted into the reward function. The forest owner's first order condition in Eq. (5) states that the benefit of a marginal unit of productive land minus the tax on this land should be equal to the foregone benefit of not setting aside this land.

$$\varphi^{f} = max_q [\rho(q, v) - \tau(q, v, z) + t(x, v, z)] \tag{3}$$

s.t. land restriction $l = x + q$, with $l, x, q \geq 0$

$$\varphi^{f} = max_q [\rho(q, v) - \tau(q, v, z) + t((l - q), v, z)] \tag{4}$$

$$\frac{\partial\rho}{\partial q} - \frac{\partial\tau}{\partial q} + \frac{\partial t}{\partial q} = 0 \tag{5}$$

Building on this small descriptive model, several aspects of policy design can be discussed.

Reserve location, continuity and sustainability. Both a regulator and the land owners will want to decide on the location of the reserves within the landscape. The forest owners most likely will want to optimize the spatial distribution of the reserves alongside production forests. A regulator, acting on behalf of society and weighting e.g. connectivity aspects more strongly, may arrive at a different optimal spatial allocation of the reserves. In terms of the model, a regulator will take into account the environmental benefit function, $\alpha(X, z)$. Note that, since we disregard possible environmental valuation motives among the forest owners themselves, this function is not a component of the forest owner's problem. We assume that the forest owner primarily takes into account the opportunity cost of creating a forest reserve, $\rho(x, v)$, i.e. the foregone benefits from forest production. The vector of biodiversity characteristics can be a set of indicators, e.g. on dead woody debris or connectivity to other forest reserves. The set of land characteristics relevant to the forest owner, vector v, may rather contain variables such as average yield or expected yearly income after taxes. Some of the land characteristics contained in vectors z and v may be positively correlated or even equal. An example could be dead woody debris which is relevant for biodiversity and average stand age. In this case, a stand that has high biodiversity value often also has high opportunity costs. Reciprocally, there are likely to be stands with low environmental value and low opportunity costs. Ideally, there are also